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Illinois University

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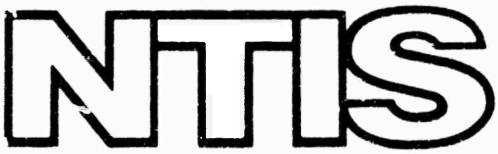

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SEMI-ANNUAL TECHNICAL REPORT OF THE CENTER FOR ADVANCED COMPUTATION
October 1, 1972 - March 31, 1973

Center for Advanced Computation
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

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REPORT SUMMARY

This document reports progress on ARPA contract DAHC04-72-C-0001 entitled "ILLIAC IV Applications Research at the Center for Advanced Computation, University of Illinois at Urbana-Champaign." The principal objective of this program is the development and testing of numerical techniques and software systems for use of ILLIAC IV over the ARPA Network. This is being accomplished through activities in the following areas:

1. Development of numerical techniques suitable for parallel processing in the areas of:
   a) Computational methods and linear algebra
   b) Linear programming
   c) Combinatorial algorithms
   d) Approximation of functions
   e) Integral equations
   f) ARPA Network
2. Development of an ILLIAC IV multispectral image processing system
3. Development of ILLIAC IV language for the phase II system
4. Development of programs in large scale calculations such as input-output economic modeling, quadratic assignment algorithms for various classes of spatial allocation problems, and atmospheric dynamics
5. Development of Network Access Computer System -- ANTS

1. APPLIED MATHEMATICS GROUP

1.1 Computational Methods in Linear Algebra:

1.1.1 Solution of Systems of Linear Equations

Numerical methods for updating the solution x in Ax=f, due to changes in rows, columns, or the disaggregation of a given row and column into m rows and columns, have been developed [17] where the number of operations required are of order n^2 instead of n^3 if the new system were to be solved "from scratch." These techniques increase the computational efficiency of handling large input-output economical models. Once the Leontief inverse is obtained for the original input-output model, the above methods permit accurate determination of the effects on the solution due to changes in the transaction data.

1.1.2 The Algebraic Eigenvalue Problem

In collaboration with members of the Chemistry Department, a direct method for synthesis of magnetic resonance spectra has been developed [6, 7]. Previously such spectra were computed by unwieldly and inefficient iterative methods. The new method simply converts the problem into one of solving a generalized eigenvalue problem. Since the matrices involved are then of special form, some thought is being given to improved methods of solving the generalized eigenvalue problem which is obtained.

An efficient parallel algorithm for finding the leading eigenvalues and eigenvectors of large sparse matrices is being developed.

This algorithm is a combination of Lanczos algorithm without reorthogonalization [14] and the simultaneous iteration method [10].

1.2 Linear Programming

The initial version of the Linear Programming algorithm for ILLIAC IV has been completed and tested on the simulator. It is written in Glypnir to enable rapid coding and will be tried on ILLIAC IV as soon as the hardware is sufficiently reliable. A document [13] describing the algorithm, a numerically stable version of the simplex method based on work by Gill and Murray [9] and Saunders [18], has been produced. Further enhancements to improve the speed of the algorithm are in hand, also theoretical work to adapt the algorithm to handle larger problems requiring auxillary storage has been done.

A matrix generator language has been developed to allow rapid specification of large matrices, mainly for use in large linear programming problems. This provides the user with the capability to create a matrix made up of many submatrices of specific types corresponding to some economic or physical model. Implementation of this algorithm is proceeding, and it is hoped that eventually it will be used to generate a code for ILLIAC IV in such a way as to allow storage of large matrices very economically. To this end some code has been written for ILLIAC IV to handle special types of substructures (e.g. diagonal matrices, lower triangular matrices.) However, much work remains to be done.

1.3 Combinatorial Algorithms

The Dulmage-Mendolsohn algorithm [8] for finding maximum

matchings in bipartite graphs was programmed in PL/I and tested as part of the work on optimal lower triangularization of sparse matrices.

A theoretical report on the quadratic assignment problem was finished and published as a CAC document [16].

A technical memorandum [15] was published on the new, parallel algorithm for clique detection. The PL/I program is now clearly commented.

A completely new algortihm for clique detection has been developed, written and tested in PL/I; given the cliques of a graph G, which is a subgraph of Graph G' with the same nodes, but fewer edges, this new algorithm finds the cliques of G' from those of G. In graphs arising from a threshold applied to a symmetric matrix, an algorithm of this type enables the threshold to vary dynamically.

1.4 Approximation of Functions

A study of simultaneous uniform approximation of sets of curves by straight lines with different intercepts but common slope was completed [2, 3]. The more difficult (but related) problem of implementing and testing an algorithm for simultaneous approximation by exponentials with common exponential factor was then tackled. Two distinct computer programs were ultimately written. In one improved approximations were constructed using the solutions of certain linear inequalities. The other program uses Remez-type techniques (successive approximations of error maxima). This second method was by far the fastest, but experience with the first method has been valuable in that it should be more easily extended to situations involving more compli-

cated approximating functions, such as sums of exponentials. More information on this work will be available in [4], a condensed version of which has been prepared for publication [5].

In another line of work, application of a previously developed theory [12] to approximation by families with a fixed point has been worked out [11]. Such approximation should be very useful in certain practical situations, for example in fitting an experimental curve by a theoretical one which according to theory must pass through a given point (the origin, for instance).

1.5 Integral Equations

A brief survey of methods available for the numerical solution of integral equations showed that an area particularly in need of study is that of methods for solving integrodifferential equations of the type arising in population dynamics or in other physical situations governed by dynamic equations which include the past history of the system (e.g. fatigue effects). Some computer experiments were done and a theoretical stability analysis was carried out for a simple first order method [1].

1.6 ARPA Network

A security code was developed for the ARPA Network. The code enables a user to log onto the system by using his code number X_i which is immediately transformed into a pseudo code word $Y_i = f(X_i)$ by the host computer. Even though Y_i and f are public knowledge it is not possible to gain access to the system without knowing X, and the equation $Y = f(X)$ cannot be solved for X, even if Y is known.

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2. ILLIAC IV MULTISPECTRAL IMAGE PROCESSING

2.1 Image Processing for Pattern Recognition

In March the Center successfully completed grant negotiations with NASA/AMES in support of system developments for ILLIAC IV interpretation of ERTS-1 imagery. CAC has completed ILLIAC codes for nonsupervised clustering of resolution elements into those terrain categories most separable with respect to spectral properties, and multivariate Gaussian statistical classification of image points into aggregate terrain categories. This work has been conducted with participation by the Laboratory for the Applications of Remote Sensing (LARS) of Purdue University. Progress is now underway to verify the correctness of these parallel codes by comparison with output from the LARS serial computing system. Reports on this work should be completed for NASA and ARPA by midsummer.

It is expected that the scope of this project will be extended in the next few months with additional support from the EROS program of USGS/DI to include the design of a more comprehensive ILLIAC-ERTS image processing system to support NASA/USGS earth resource monitoring objectives.

In addition to present contractural commitments, CAC is investigating a new methodology for general image processing and pattern recognition work which is expected to contribute to the solution of

image registration problems occurring within the analysis of resource boundary changes over time. The method employed also seems applicable to a wider class of pattern recognition problems where prototype-derived patterns are to be classified. A report on this work to NASA and ARPA is forthcoming.

3. ILLIAC IV LANGUAGE DEVELOPMENT FOR THE PHASE II SYSTEM

3.1 IDOL

Although the IDOL report was not an overwhelming success (from the point of view that it elicited no support for implementation), the work performed to define IDOL revealed that there is something to be gained by applying the storage management techniques which form the foundation for the IDOL approach in contexts other than that of ILLIAC IV. A language and compiler which could provide accurate working set information to an operating system prepared to use it could (on the basis of Belad 's work) permit a 100 per cent increase in throughput in the same physical memory. Generalization of the techniques suggested could be used to intelligently control the flow of information between levels of a memory hierarchy (of more than two levels).

4. ECONOMIC RESEARCH GROUP

4.1 STEP I

During this period, work under ARPA support of STEP I was completed. The STEP I system has been used for several forecasts of occupational employment for the United States and is to be maintained and applied as need arises.

The principal research activity of the group under ARPA support has emphasized the development of efficient computational algorithms for large linear computations in which matrices are subject to modifications of one or a few rows or columns.

4.2 STEP II

Members of the group responsible for STEP II have left employment at the Center for other positions. As a result, planning and design of STEP II under ARPA support has been temporarily suspended.

4.3 MEASURE

Work on the MEASURE activity has been transferred to the Information System Group.

5. NETWORK SYSTEMS GROUP

5.1 Project to Interface the B6700 to the ARPA Network

During the period, the University of California at San Diego (UCSD) 6700 entry to the network was improved and expanded. The Center will no longer have any responsibility in the area of interfacing Burroughs B6700's to the network.

5.2 ARPA Network Terminal System Development

During the reporting period, development of ANTS progressed in completing the Mark I system, and initial design and coding efforts on the Mark II system progressed.

The Mark I system is now stabilized and a crash rate of 1 to 3 per day has been attained. No further activities will be involved in upgrading or maintaining Mark I as all Center personnel will be involved in the development of the Mark II system.

The remaining efforts of the group during the period were to complete software necessary to operate with the UCSD computer center via the network, to upgrade the PEESPOL compiler for additional support in developing Mark II ANTS for the next reporting period and to lay down the design specifications for the Mark II system.

The Mark II system design is complete to the point of allowing initial coding and debugging activities to begin. It is expected that during the second quarter of 1973, the Mark II system will be brought to an operational status, first to a level equivalent to the Mark I system

and then later to include increasing numbers of peripheral devices, protocols and associated activities.

5.3 ARPA Network Usage

During the reporting period, network usage continued very heavily on the UCSD B6700 system, UCLA 360/91 (both for RFE and TSO usage), various Tenex systems around the network (predominantly USC-ISI), the Multics system, and the Ames TSS 360/67 system. Initial efforts were begun during the reporting period to begin access and experimental usage of the ILLIAC IV complex at Ames.

5.4 Further Installation of ANTS Systems on the Network

During the reporting period, more contacts were made with additional sites for information as to the availability of an ANTS system to provide those sites with access to the network. The University of California at Los Angeles has elected to replace their Sigma 7 computer system with an ANTS for access to the network in the network measurement project supported by ARPA. Additionally, further work is in progress with the Army to establish possible follow-up on activities in the installation of additional sites.

5.5 Graphics Support for Center Projects

With the advent of the UCSD 6700 system as a service site on the network, graphics activities were continued and the development of a full blown user-oriented graphics package initiated. Fancy ARPA Network Graphics System (FANGS) will provide a very sophisticated and highly interactive system for doing graphical analysis and display of user desired

imagery. Additionally, programs were developed for bringing back graphical images to various CAC equipment such as the Gould plotter, Computek graphics copies, the IMLAC Display, and a soon to be acquired drum plotter system.

Additional work is being initiated in the production of half tone imagery on the IMLAC Display as a supporting function to the ERTS imagery project which will be developing algorithms and analysis system on ILLIAC IV for ERTS imagery.

5.6 Hardware Acquisition

During the reporting period, negotiations were completed with the Digital Equipment Corporation for additional hardware at the Center based on the advanced concepts PDP-11 model 45 processor and memory system to provide Center research personnel with an advanced capability access system for the ARPA Network. The software system, known as The Network Imbedded Computer Executive (NICE) will be developed for the 11-45. Design activities will begin during the next reporting period.

5.7 Laboratory for Atmospheric Research Support

Support for the University of Illinois at Urbana-Champaign's Laboratory for Atmospheric Research (LAR), under the direction of Professor Ogura, consisted of the procurement of a drum plotting device, to be attached to the Center's ASTS system, and the writing of graphics packages at several network sites for display of the laboratory's research results.

The drum plotter was ordered during the reporting period and will be delivered in May, 1972.

Basic graphics display software was written on the UCLA 360/91 and the University of Southern California's Information Services Institute's PDP-10 for display of the laboratory's meteorology research results. Graphics images can be returned from either place to the IMLAC display, the Computek storage scope or the GOULD printer/plotter attached to ANTS

During the next reporting period, inhouse graphics display software will be written at UCLA and USC-ISI to provide more sophisticated output of LAR results. The plotter will be interfaced to ANTS and added to the repertoire of graphics devices available to LAR researchers.

6. ADMINISTRATION

6.1 Fiscal Status

Actual expenditures through 30 September 1972: $1,527,323.

Estimated expenditures and obligations for the six month period covered in this report (1 October 1972 - 31 March 1973):

October	106,734
November	132,550
December	108,972
January	124,933
February	86,452
March	141,058
	700,699

Total expenditures and obligations through 31 March 1973: $2,228,022.

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